2.12 THE BEST ANALYZED AIR-SEA FLUXES FOR SEASONAL FORECASTING

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1. INTRODUCTION

The Environmental Modeling Center is preparing to implement a new coupled ocean-atmosphere model to make seasonal forecasts. Initial conditions for both the atmosphere and ocean are needed to initialize a coupled atmosphere-ocean forecast model. NCEP produces global atmospheric analyses with three systems: the operational global data assimilation system (GDAS), the NCEP/NCAR reanalysis run on current data as CDAS and the NCEP-2 reanalysis run as CDAS-2. The operational GDAS is run at spectral resolution T254 and 64 levels; CDAS and CDAS-2 are run at T62 with 28 levels. CDAS incorporates the atmospheric model that was operational in 1995; the model used in GDAS incorporates 9 years of improvements from the CDAS model. CDAS-2 corrected mistakes in the NCEP/NCAR reanalysis and modified the physics.

NCEP produces global ocean analyses with a global ocean data assimilation system (GODAS) (Behringer, personal communication). It is based on the Geophysical Fluid Dynamics Laboratory (GFDL) Modular Ocean Model 3 (MOM3) (Pacanowski and Griffies, 1998). Its domain extends from 74S to 64N and has a zonal resolution of 1°. Its meridional resolution of 1/3° between 10S and 10N gradually increases until it is fixed at 1° poleward of 30S and 30N. There are 40 levels in the vertical with 27 in the upper 400 m.

GODAS analyzes temperature and salinity and is forced by wind stress, heat flux and precipitation minus evaporation. Sea surface temperature is relaxed to a weekly NCEP SST analysis; surface salinity is relaxed to the Levitus monthly climatology.

In implementing a new seasonal forecast system, hind-casts need to be run over the last 20 years to produce calibrations for real-time forecasts as essential guidance for users on forecast reliability. The NCEP-2 reanalysis was used to initialize and verify the atmospheric component of the coupled seasonal forecast system. An ocean reanalysis from 1981 to the present has been performed with GODAS making use of fluxes from the NCEP-2 reanalysis. The NCEP-1 reanalysis has too weak zonal surface stress in the equatorial Pacific.

The operational global forecast system yields substantially better atmospheric forecasts than the systems used for CDAS and CDAS-2, has higher horizontal and vertical resolution and has the benefit of several years of experience, improvement and development that CDAS and CDAS-2 did not. This implies that GDAS analyses are more realistic depictions of the atmosphere than CDAS or CDAS-2 and suggests that surface fluxes from GDAS may be more accurate than surface fluxes from CDAS-2. The atmospheric component of the seasonal forecast model itself is a version of the operational global forecast system of 2003, suggesting that GDAS's atmospheric fields and surface fluxes should be more consistent with the seasonal forecast model than CDAS-2.

The question for real-time seasonal forecasts is which atmospheric analyses to use to initialize the atmospheric component and which surface fluxes to use in the ocean analysis. For hind-casts, one is limited to CDAS-2 since no reanalysis currently exists with GDAS. For the real-time forecasts, should one use GDAS whose analyses and fluxes should be more realistic than CDAS-2 and should be more consistent with the seasonal forecast system or should one use NCEP-2 to ensure consistency with the hind-casts?

An alternative suggestion was to use surface fluxes from long integrations of the coupled model in GODAS to avoid problems with spin-up due to initial imbalances in model physics because of differences between the model climatology and the data analyzed by GODAS. Experiments indicated that the resulting seasonal forecasts had less skill in forecasting equatorial Pacific SSTs than seasonal

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forecasts from GODAS driven by surface fluxes from the NCEP-2 reanalysis.

This paper compares climatologies of surface fluxes from the NCEP-2 reanalysis to other long-term records to investigate the realism of NCEP-2 surface fluxes and compares surface fluxes from CDAS-2 to surface fluxes from GDAS in recent years to establish the significance of the differences and whether GDAS surface fluxes are more realistic than CDAS-2 fluxes.

2. Zonal Surface Stress in the tropical Pacific

Fig. 1 compares long-term means of zonal surface stress from 4 sources. The four are fairly similar, especially in pattern. The NCEP-2 reanalysis has the weakest stress near the equator but the strongest south of Hawaii. Note both reanalyses have bulleyes over Hawaii, reflecting the difficulty of incorporating data from a land station on an island whose scale is less than the models' resolution.

Fig 2 shows the correlation of monthly mean zonal wind stress anomalies from FSU with the NCEP-2 reanalysis. Correlations are high away from the equator and in the western Pacific and low near the equator in the eastern Pacific where the variability in stress is low (figure 3). Fig.3 compares the month to month variability in zonal wind stress in FSU and the NCEP-2 reanalysis. The two are similar in variability, but FSU is more variable near the equator.

3. GDAS vs CDAS-2

This section compares fields from the operational analyses in recent years to fields from CDAS-2, the continuation of the NCEP-2 reanalysis. Fig. 4 compares precipitation for one year as estimated by CMAP, a precipitation estimate prepared by the Climate Prediction Center from rain gauges and satellite-bases estimates, GDAS and CDAS-2. The pattern of precipitation in the operational analysis clearly resembles the independent estimate more in the tropical Pacific. CDAS-2 has problems with the dry zone along the equator in the eastern Pacific and the orientation of the South Pacific convergence zone. This reflects the higher resolution of the operational analysis and improvements in the atmospheric physics since the NCEP-2 reanalysis. The magnitudes of precipitation, especially local, are different in the three estimates and which magnitudes are correct over the ocean is not clear.

Table 1 compares the global mean ocean surface energy budget from 5 climatologies and two estimates from a single year. Of the 5 climatologies, three are based on reanalyses; their energy budget is much closer to global balance than the COADS-based estimate (SOC). SRB1 is based on satellite observations; however, its net long wave is significantly lower than other estimates. NCEP-2 has a lower global mean sensible heat flux than NCEP-1, perhaps reflecting a change in boundary layer parameterization.

During August 2002-July 2003, the operational analysis had a greater surface energy imbalance than CDAS-2, reflecting higher net short wave radiation than other estimate.

Fig. 5 compares surface stress from GDAS and CDAS-2 for 3 years, Dec. 2000-Nov. 2003. GDAS has a stronger time-mean surface stress near the equator in the Pacific, but is weaker in mid-latitudes. The time-mean surface stress is 10-30% different over much of the ocean. The mean RMS difference of monthly means over the three years is more than 30 % different in the western Pacific and equatorial Indian Ocean. The impact of these differences on ocean analyses and on seasonal forecasts has not been established, but the differences appear significant.

Fig. 6 (top) shows the difference between the NCEP-2 reanalysis and SRB-1 in surface net short wave radiation. The NCEP-2 reanalysis has too little net short wave in the tropics and too much in mid-latitude. Fig. 6 (bottom) shows the difference in surface net short wave between GDAS and CDAS-2. The changes are qualitatively in the right direction; however the decrease in higher latitudes is too weak and the increase in the tropics is too strong.

Fig. 7 compares 3-year mean net heat flux from CDAS-2 and from GDAS. CDAS-2 has relatively little net heat flux into the oceans in the tropics and tends to have more into the ocean in midlatitudes than in the tropics. GDAS appears to have a more reasonable pattern, with more into the ocean in the tropics and a little less into the ocean in mid-latitudes.

These results indicate that significant differences exist between CDAS-2 and GDAS in surface stress and that GDAS appears to have better patterns of surface fluxes and precipitation than CDAS-2, but that global mean fluxes are less realistic in GDAS than in CDAS-2.

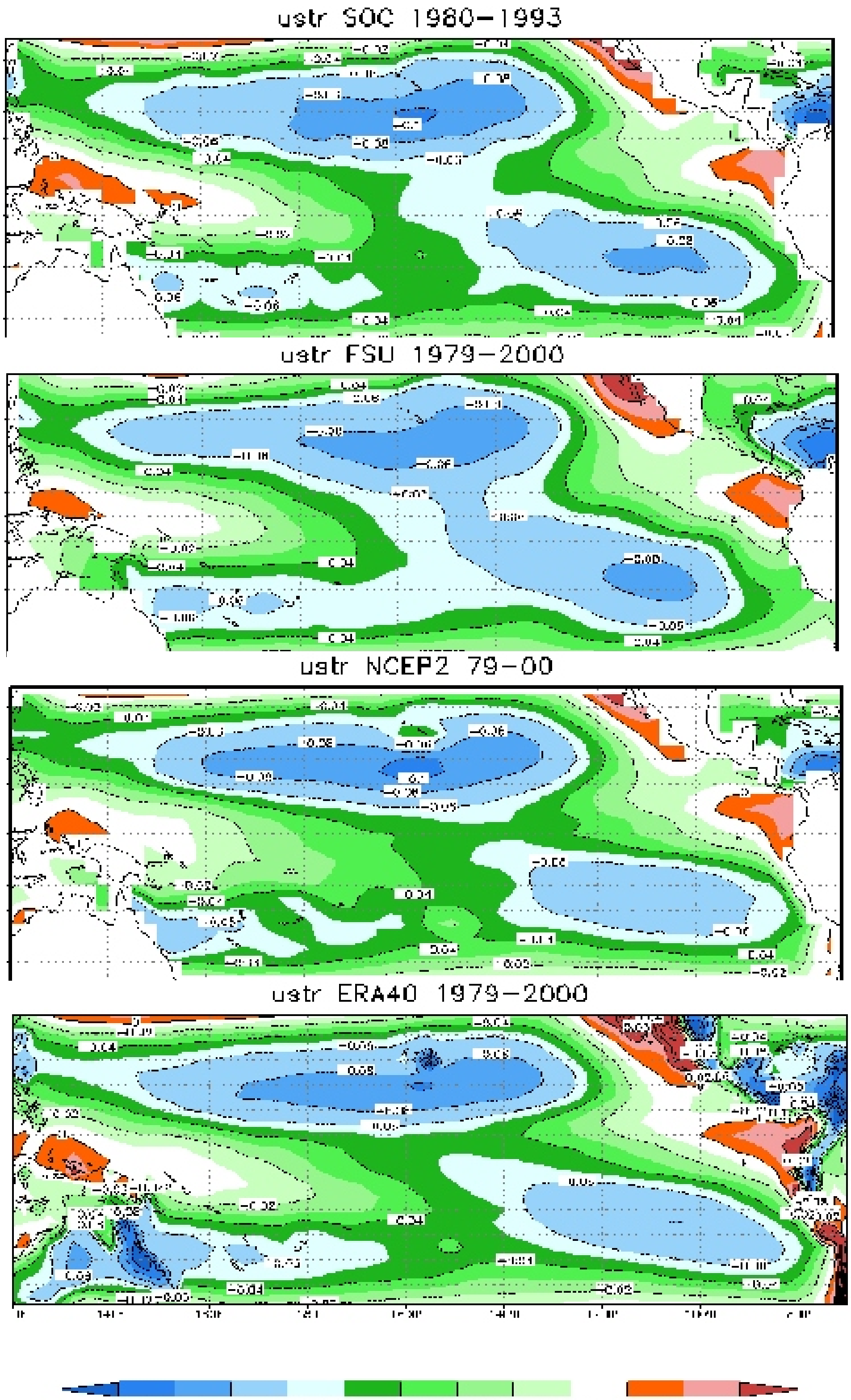

Fig. 1 Time-mean zonal surface stress from (top) SOC based on COADS observations for 1980-93, (2nd from top) FSU, (2nd from bottom) NCEP-2 reanalyses (bottom) ERA-40 reanalyses. The last three are for 1979-2000.

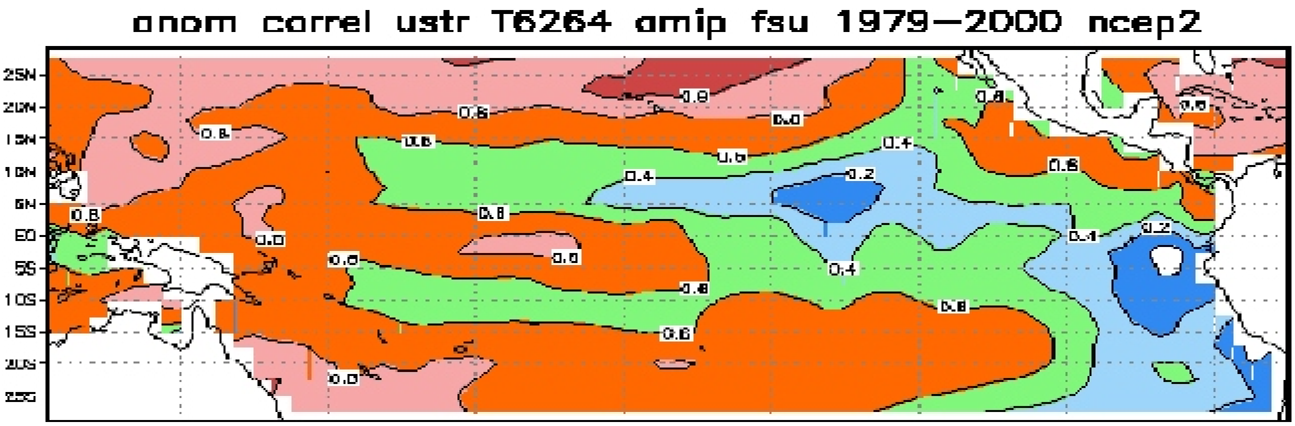

Fig. 2 Correlation of monthly mean anomalies of zonal surface stress for 1979-2000 from the NCEP-2 reanalysis and FSU. Orange indicates a correlation of .6 to .8.

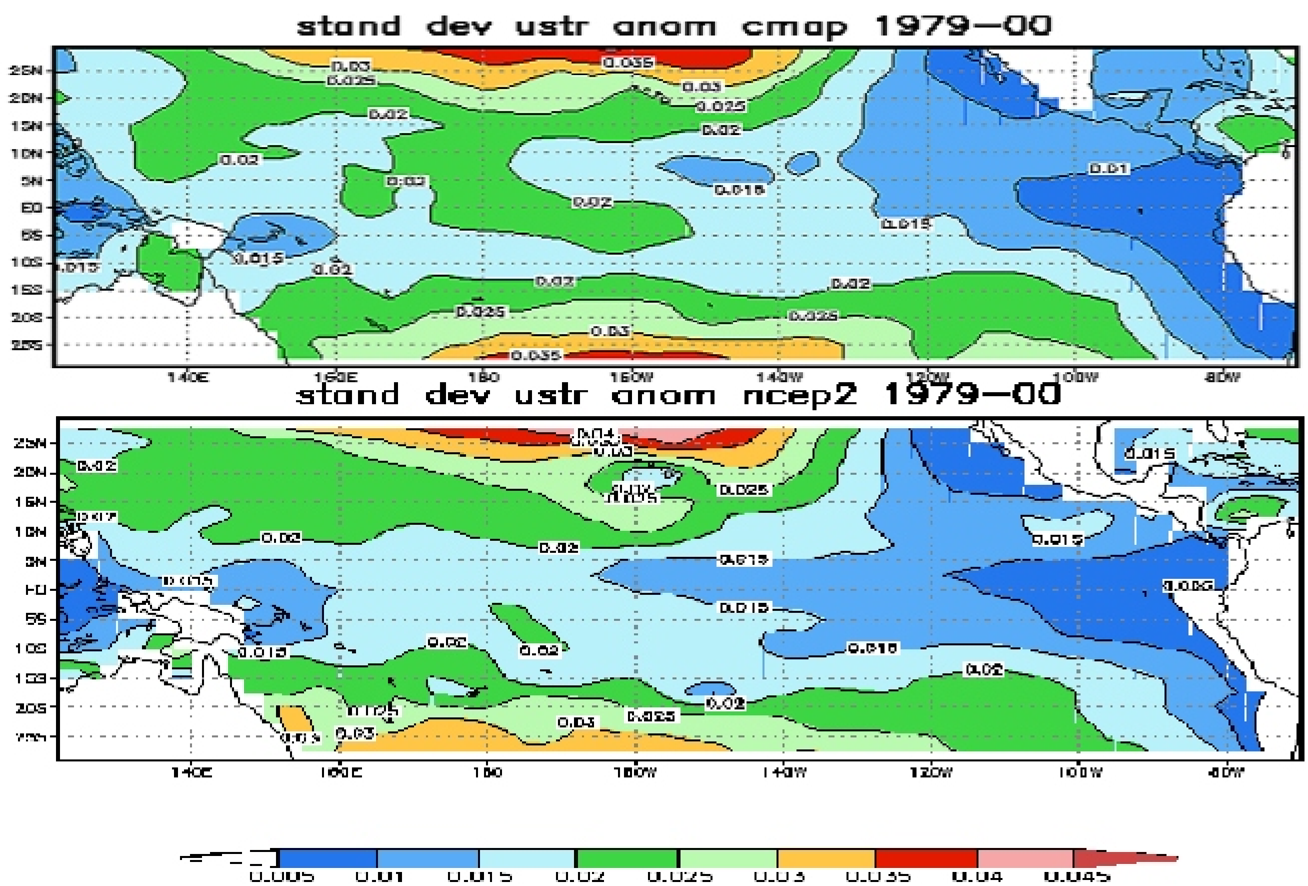

Fig. 3 Standard deviation of monthly mean anomalies of zonal surface stress for 1979-2000 from (top) FSU and (bottom) the NCEP-2 reanalyses.

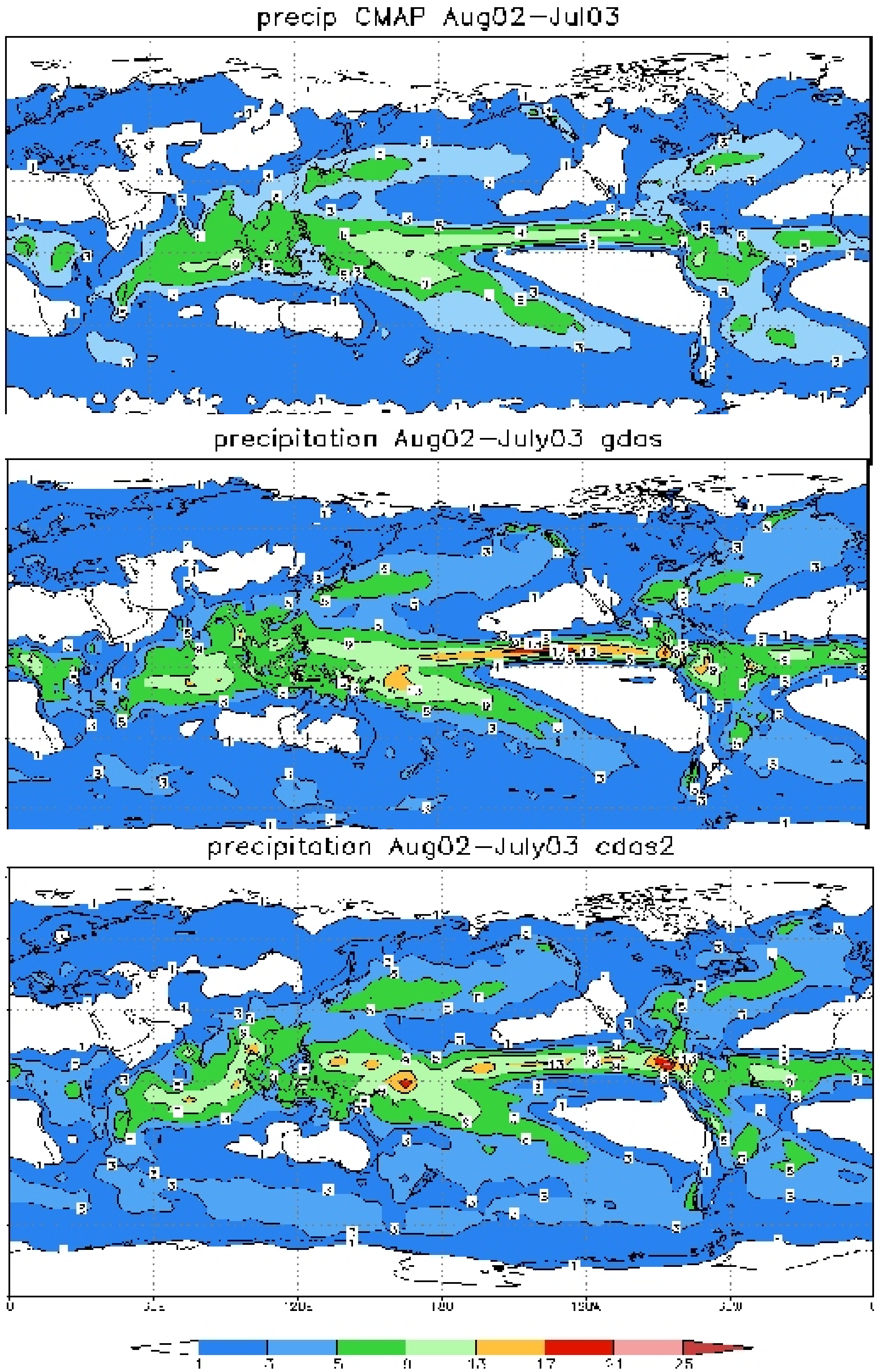

Fig. 4 Mean precipitation for Aug. 2002-July 2003 from (top) CMAP, (middle) GDAS and (bottom) NCEP-2 reanalysis in mm/.day.

Global Mean Ocean Heat Budget

	SOC 80-93	SRB1 83-91	NCEP1 80-93	NCEP2 80-93	ERA15 81-92	CDAS2 Aug02-Jul03	oper Aug02-Jul03
LH	90		92	103	103	113	109
SH	7		11	5	10	6	6
NSW	176	173	165	167	160	169	192
NLW	49	42	57	51	50	51	67
NHF	30		6	7	-4	-1	11

Table 1 Global mean ocean energy balance for 5 climatologies (left) and for August 2002-July 2003 (two right columns) in Watts/msq.

4. FUTURE PLANS

EMC's plan is to use the same global model for seasonal and weather forecasts. Because of the computational burden involved in running hind-casts as part of the implementation of a new seasonal forecast model, it is planned to change the seasonal forecast model only every 3-5 years and to implement the then-operational global model. To make sure that the seasonal forecast system is consistent, it is planned to conduct a new atmospheric reanalysis of the satellite era making use of the operational data assimilation and to use that reanalysis to generate a new ocean reanalysis and a new land surface reanalysis. (Eventually, a truly coupled land-ocean-atmosphere-cryosphere data assimilation will be used.) Those reanalyses and new CDAS will be used for the hind-casts and the operational real-time seasonal forecasts, ensuring that a consistent system is used for all parts of the seasonal forecasts. The new reanalyses should also provide improved estimates of the variability of weather and climate every few years; community feedback from the new reanalyses should give invaluable feedback on the performance of EMC's global model.

EMC plans to make an extensive archive of fields from the hind-casts available to the scientific community through NOMADS. Following implementation of the seasonal forecast system this year, EMC will begin work on its replacement. EMC plans to introduce MOM4, a sea-ice model, improved stratus clouds and higher resolution.

REFERENCES

Pacanowski, R.C., and S.M. Griffies, 1998: MOM3.0 Manual, NOAA/Geophysical Fluid Dynamics Laboratory, Princeton, USA 08542

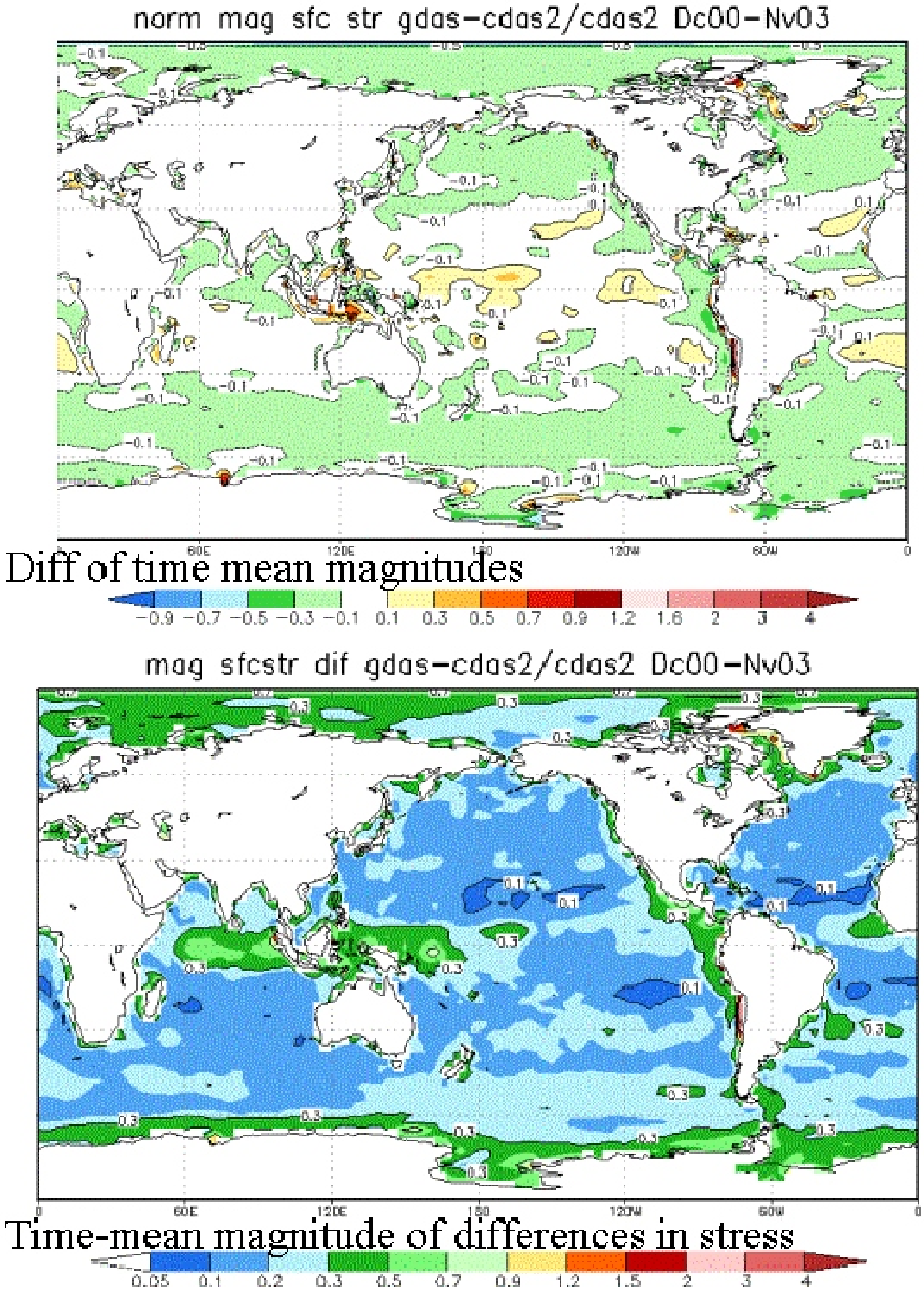

Fig. 5 Differences in surface stress between GDAS and CDAS 2 for Dec.2000-Nov. 2003 normalized by the RMS surface stress in CDAS2. (Top) Difference in the 3-year mean magnitudes of the surface stress (Bottom) Time-mean RMS magnitude of the difference in monthly mean surface stress.

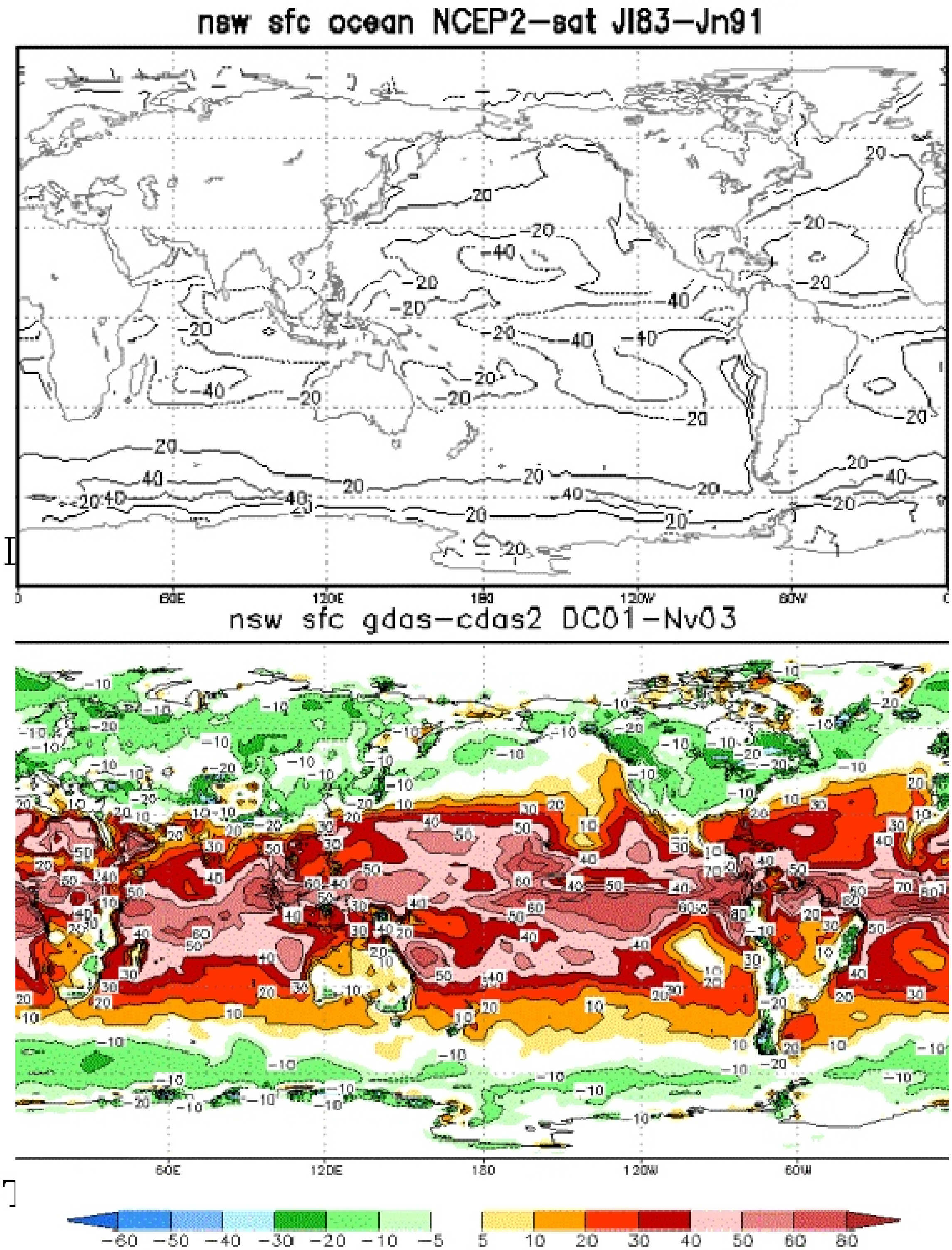

Fig. 6 Difference in net short wave radiation at the surface between (top) NCEP-2 and SRB-1 for July 1983-June 1991 and between (bottom) GDAS and CDAS-2 for Dec. 2001-Nov. 2003 in watts/msq.

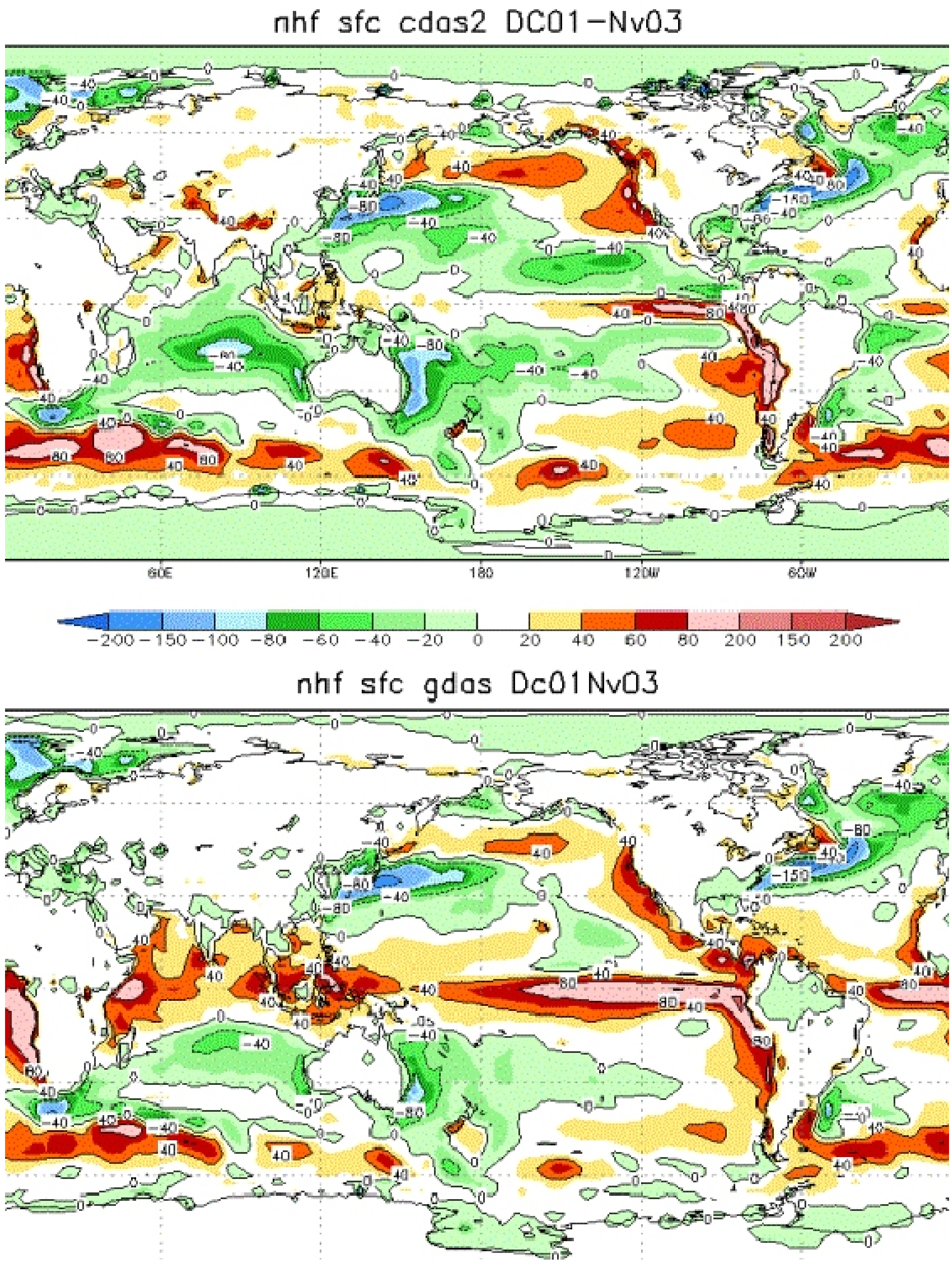

Fig. 7 Surface net heat flux into the ocean for Dec. 2001-Nov. 2003 for (top) CDAS-2 and (bottom) GDAS for Dec. 2001-Nov. 2003.